RESEARCH ARTICLE

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# Scoring System for Predicting Breast Cancer Risk Among Women in Regions with Limited Healthcare Infrastructure in Indonesia

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## Abstract

**Objective:** Breast cancer (BC) remains the most common malignancy and a leading cause of cancer-related mortality among Indonesian women, with many cases detected at advanced stages due to limited screening and healthcare resources. Existing risk prediction models, developed in Western populations, may not adequately capture locally relevant determinants. **Methods:** A hospital-based case–control study was conducted at a national referral hospital in West Sumatra, Indonesia. A total of 250 histologically confirmed BC cases and 250 age-matched controls were enrolled. Data on reproductive, familial, and lifestyle factors were collected using structured questionnaires and medical records. Logistic regression was applied to identify significant predictors, which were then integrated into a scoring system. The discriminatory ability was assessed using receiver operating characteristic (ROC) analysis. **Results:** Significant predictors of BC included late menopause (≥50 years; adjusted OR 4.50), first pregnancy at ≥30 years (AOR 2.70), family history of BC (first-degree AOR 30.22; second-degree AOR 3.82), short breastfeeding duration (<12 months; AOR 41.24), long-term oral contraceptive use (≥12 months; AOR 1.94), overweight (AOR 2.37), obesity (AOR 3.94), high-fat diet (AOR 25.75), low physical activity (AOR = 14.29), moderate physical activity (AOR = 4.08). The scoring system, with a maximum score of 18, demonstrated excellent predictive accuracy (AUC 0.907; 95% CI: 0.879–0.931). A cut-off score >5 provided optimal sensitivity (84%) and specificity (80%). **Conclusion:** The proposed scoring system offers a practical, context-specific tool for early risk assessment of breast cancer in Indonesian women, particularly in regions with limited healthcare infrastructure. Its implementation may support targeted screening and resource allocation.

**Keywords:** Breast cancer- Risk prediction- Scoring system- Reproductive factors- Indonesia

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## Introduction

Breast cancer (BC) is the most common malignancy among women worldwide and remains a leading cause of cancer-related mortality, including in Indonesia [1]. National data indicate that BC accounts for approximately 16.7% of all cancers among Indonesian women [2]. The highest prevalence has been reported in Yogyakarta (2.4%), followed by East Kalimantan (1.0%) and West Sumatra (0.9%) [3]. Alarmingly, more than half of Indonesian women are diagnosed at advanced stages, whereas in many Western countries nearly 80% of cases are detected at an early stage [4, 5]. This disparity highlights inequities in screening practices, healthcare access, and available resources across regions [6].

Risk prediction models such as Gail, Claus, Tyrer–Cuzick, and BOADICEA have been widely applied in Western countries [7-9]. However, these models were developed in Western populations and may not adequately reflect the risk factor profiles of Indonesian women [10]. Local epidemiological characteristics including earlier menarche, later menopause, and distinctive reproductive histories may influence BC risk differently [11, 12]. In addition, lifestyle-related exposures such as alcohol consumption, smoking, and hormone replacement therapy are relatively uncommon in Indonesia compared with Western settings [13, 14]. These differences underscore the need for a risk assessment tool that incorporates reproductive, familial, and lifestyle determinants relevant to the Indonesian context.

Healthcare infrastructure limitations further exacerbate the problem. In West Sumatra, as in many other provinces, mammography facilities are scarce and concentrated in urban areas, leaving rural women with minimal access [15]. Screening is largely opportunistic rather than population-based, resulting in inconsistent coverage.

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Even when diagnostic services are available, shortages of trained oncologists, radiologists, and specialized nurses delay timely detection and treatment [4]. Public awareness of early warning signs remains low, hampered by cultural barriers, inadequate health literacy, and limited outreach. Financial constraints and unequal distribution of healthcare resources compound these challenges, contributing to late-stage diagnoses among women from low-income or remote households [4, 5]. Furthermore, existing breast cancer outreach programs are often fragmented and lack standardized educational materials tailored to local languages and cultural beliefs, limiting their effectiveness in rural communities. Many primary care centers (Puskesmas) lack basic breast examination training tools, structured referral pathways, and consistent reporting systems, hindering coordinated early detection efforts across districts in West Sumatra.

Given these systemic barriers, a locally developed scoring system offers a practical strategy to support early risk assessment in resource-limited settings [7, 12]. Unlike population-wide mammography screening, a scoring system can be applied at the community or primary care level to stratify women based on their likelihood of developing BC, thereby guiding referrals and prioritizing scarce diagnostic resources [5]. Current data in Indonesia, however, are mostly derived from small-scale surveys and hospital records, which provide fragmented evidence and overlook the combined impact of reproductive, familial, and lifestyle factors [4, 16]. In addition, the absence of region-specific risk assessment tools limits the ability of local healthcare providers to identify high-risk women early, and existing national guidelines do not yet integrate structured risk prediction methods that are feasible for low-resource settings.

Therefore, this study aimed to develop a scoring system for predicting BC risk among women in Western Indonesia, particularly in regions with limited healthcare infrastructure. By integrating locally relevant determinants into a practical tool, this study seeks to enhance risk stratification, inform preventive strategies, and support equitable cancer control efforts in low-resource settings.

## Materials and Methods

*Study design and setting*

This study adopted a hospital-based case-control design and was conducted at a national referral hospital in West Sumatera, Indonesia. The data collection period extended from June and August 2025.

*Research participants and sample size calculation*

The research participants consisted of two groups. The case group included women with a confirmed diagnosis of BC established through histopathological examination, while the control group comprised women with no personal history of breast or ovarian cancer. The sample size was determined using the formula for comparing two proportions, calculated with the R statistical environment. Assuming a 95% confidence level, 80% power, and an estimated proportion of exposure of 42% among cases compared with 30% among controls [17], the minimum required sample size was 250 participants per group, for a total of 500 participants.

The inclusion criteria for the case group were female patients with a positive diagnosis of BC, confirmed by pathology reports, and who had complete medical and interview data. For the control group, inclusion required female patients with no history of BC or ovarian cancer, also with complete data available. Male BC survivors were excluded from both groups to avoid confounding. Controls were selected from the same hospitals using hospital controls and were matched to cases by age and sex within a range of ±5 years to minimize confounding effects. Convenience sampling was employed for recruitment, but strict matching ensured comparability between groups.

*Research instruments*

Data on risk factors were collected through structured face-to-face interviews conducted by trained interviewers using standardized questionnaires. The interviews explored risk factors associated with BC. The reproductive risk factors assessed in this study included the age was grouped into <50 years and ≥50 years [18], while age at menarche was categorized as early (7–11 years), ideal (12–13 years), or late (>13 years) [19]. Similarly, age at menopause was classified as <50 years or ≥50 years [18]. Reproductive history included age at first pregnancy, categorized as <20 years, 20–29 years, or >30 years [19], and parity, which was grouped as nulliparous, primiparous, or multiparous (≥2) [19]. History of hormone replacement therapy (HRT), which was categorized as either "used" or "never used" [20], as well as oral contraceptive (OC) use, classified according to duration into ≥12 months or <12 months [21]. Lactation duration was also recorded and grouped into ≥12 months or <12 months [22]. Marital status was categorized as either "single/widowed" or "married" [23].

Family history of BC was assessed separately for first-degree relatives (mother, sister, or daughter) [9, 12] and second-degree relatives (aunt or cousin), with participants categorized as "positive" if such relatives had been diagnosed with BC, and "negative" if no family history was present [9, 12].

Information regarding alcohol consumption was obtained and classified into "≤5 drinks/week," ">5 drinks/week", or "non-drinker for ≥10 years" [24]. Smoking status was determined by whether participants had smoked regularly in the last 12 months ("active smoker") or had never smoked or quit smoking for at least 12 months ("non-smoker") [25]. Body Mass Index (BMI) was calculated using direct measurements of weight and height and categorized into "normal" (18.5–23.49 kg/m²), "overweight" (23.5–24.99 kg/m²), or "obese" (≥25 kg/m²) [26]. Physical activity was assessed using the World Health Organization (WHO) Global Physical Activity Questionnaire (GPAQ) and analyzed with the STEPwise method, expressed as Metabolic Equivalent minutes per week (MET-min/week). Based on accumulated activity, participants were classified as "low" (<600 MET-min/week), "moderate" (600–2999 MET-min/week), or "high" (≥3000 MET-min/week) [27]. Dietary habits were measured using the Semi-Quantitative Food Frequency

Questionnaire (SQ-FFQ), with particular attention to high-fat and high-calorie intake. The adequacy of dietary intake was compared to the Recommended Dietary Allowance (RDA) and categorized as either "excess" (>100% RDA) or "sufficient" (≤100% RDA) [28].

To ensure data reliability and minimize interviewer bias, all field investigators underwent standardized training and adhered to uniform interview procedures. Where possible, participants' self-reported information on reproductive history and lifestyle factors was cross-validated with available medical records. This methodological approach strengthened the validity of the data and reduced the potential for recall or reporting bias.

*Data management*

All data obtained in this study were managed through a structured and secure process to ensure accuracy, completeness, and confidentiality. Each participant was assigned a unique identification code to anonymize personal information. Questionnaires from interviews and extracted data from medical records were checked daily by the field coordinator for completeness and consistency before being entered into the database. Data entry was carried out independently by two trained data clerks using double-entry procedures in a password-protected database to minimize errors. Any discrepancies between the two datasets were resolved by cross-checking the original source documents. R software was used for cleaning, coding, and analysis. Range and logic checks were applied to identify outliers or inconsistent values, which were then verified against source records. To protect confidentiality, both hardcopy and electronic data were stored securely. Hardcopy questionnaires and consent forms were kept in locked cabinets accessible only to the principal investigator and authorized research staff. Electronic data files were stored on encrypted devices and backed up on a weekly basis. Names and personal identifiers were kept separately from research data and were not used in any analysis or publication. Only members of the research team with assigned data access rights were permitted to handle the dataset. Before analysis, all data were de-identified, and results were presented in aggregate form to ensure participant privacy.

*Data analysis*

The initial step of analysis involved bivariate testing using the Chi-square test to examine the association between risk factors and BC status. A significance level of $p<0.05$ was used to define statistical significance, while variables with $p<0.25$ in bivariate analysis were carried forward into multivariable modeling to avoid excluding potentially important predictors. Logistic regression analysis was then applied to estimate adjusted odds ratios (ORs) with 95% confidence intervals (CIs). Model calibration was assessed using the Hosmer–Lemeshow goodness-of-fit test. To construct the breast cancer risk scoring model, receiver operating characteristic (ROC) curve analysis was performed, and the optimal cut-off point was determined using the Youden Index (J). The diagnostic performance of the model was further evaluated by calculating sensitivity, specificity, and the area under the curve (AUC).

## Results

Breast cancer risk factors among case and control groups in a National Referral Hospital in West Sumatra, Indonesia (Table 1).

Table 1 presented the data indicated several significant factors associated with BC risk, including age at menopause, age at first pregnancy, family history of BC (first and second degree), breastfeeding duration, oral contraceptive use, BMI, high-fat diet, and physical activity ($P<0.05$). Crude and adjusted odds ratios of identified risk factors associated with breast cancer among Indonesian women (Table 2).

Table 2 showed the adjusted odds ratios (OR) for BC risk factors indicate several significant associations. Women who experienced menopause at ≥50 years had an adjusted OR of 4.50 (95% CI: 2.00, 10.12). Similarly, women who had their first pregnancy at ≥30 years had an adjusted OR of 2.70 (95% CI: 1.11, 6.56), indicating that delayed first pregnancy is a significant risk factor. A first-degree family history of BC was strongly associated with BC risk, with an adjusted OR of 30.22 (95% CI: 3.16, 293.09). Women with a second-degree family history also had an increased risk, with an adjusted OR of 3.82 (95% CI: 1.05, 13.86). The data also indicated that women who breastfed for <12 months had a significantly higher risk, with an adjusted OR of 41.24 (95% CI: 2.84, 598.42). The use of oral contraceptives for ≥12 months was associated with an adjusted OR of 1.94 (95% CI: 1.01, 3.74). In terms of BMI, both overweight and obesity were linked to higher BC risk, with adjusted ORs of 2.37 (95% CI: 1.28, 4.40) for overweight and 3.94 (95% CI: 1.79, 8.66) for obesity. A high-fat diet was strongly associated with an increased risk, with an adjusted OR of 25.75 (95% CI: 10.71, 61.91). Lastly, low physical activity was significantly associated with an increased risk, with an adjusted OR of 14.29 (95% CI: 6.64, 30.76), followed by moderate physical activity, which had an adjusted OR of 4.08 (95% CI: 2.21, 7.53).

Development of the breast cancer risk scoring system (Table 3). Table 3 outlined the variables that contributed to the BC risk scoring system. These variables included age at menopause (≥50 years, score = 2), age at first pregnancy (≥30 years, score = 1), a first-degree family history of BC (score = 1), a second-degree family history of BC (score = 1), breastfeeding duration (<12 months, score = 1), use of oral contraceptives (≥12 months, score = 1), overweight (score = 1), obesity (score = 2), high-fat diet (score = 3), low physical activity (score = 3), and moderate physical activity (score = 2). The maximum total score, based on these risk factors, was 18. The BC risk screening tool, with a constant of -5.18 and a $P<0.001$, was statistically significant, confirming that the scoring system was an effective method for predicting BC risk.

Calculation of poor prognosis probability based on breast cancer risk score (Table 4). Table 4 presented the calculation of the probability of poor prognosis based on the BC risk score. The formula used for calculation was $y = -5.18 + 0.55 \times$ total score, where the total score corresponded to various risk factors associated with BC.

Table 1. Breast Cancer Risk Factors among Case and Control Groups in a National Referral Hospital in West Sumatra, Indonesia

| Risk factor | Case (f/%) (n=250) | Control (f/%) (n=250) | P-value |
|---|---|---|---|
| A. Reproductive factors | | | |
| Age (years) | | | 0.178† |
| <50 | 128 (51.2) | 144 (57.6) | |
| ≥50 | 122 (48.8) | 106 (42.4) | |
| Age at menarche (years) | | | 0.310 |
| 7-11 | 22 (8.8) | 20 (8.0) | |
| 12-13 | 124 (49.6) | 109 (43.6) | |
| >13 | 104 (41.6) | 121 (48.4) | |
| Age at menopause (years) | | | <0.001*† |
| <50 | 94 (37.6) | 146 (58.4) | |
| ≥50 | 156 (62.4) | 104 (41.6) | |
| Age at first pregnancy (years) | | | <0.001*† |
| <20 | 43 (17.2) | 42 (16.8) | |
| 20-29 | 152 (60.8) | 185 (74.0) | |
| ≥30 | 55 (22.0) | 23 (9.2) | |
| Parity | | | 0.593 |
| Nulliparous | 16 (6.4) | 12 (4.8) | |
| Primiparous | 51 (20.4) | 58 (23.2) | |
| Multiparous | 183 (73.2) | 180 (72.0) | |
| Breastfeeding duration (months) | | | <0.001*† |
| <12 | 48 (19.2) | 1 (0.4) | |
| ≥12 | 202 (80.8) | 249 (99.6) | |
| Use of oral contraceptives (months) | | | <0.001*† |
| <12 | 153 (61.2) | 215 (86.0) | |
| ≥12 | 97 (38.8) | 35 (14.0) | |
| Hormonal replacement therapy | | | 1.000 |
| Yes | 1 (0.4) | 0 (0) | |
| No | 249 (99.6) | 250 (100.0) | |
| Marital status | | | 0.399 |
| Single/widowed | 16 (6.4) | 22 (8.8) | |
| Married | 234 (93.6) | 228 (91.2) | |
| B. Familial factors | | | |
| A first-degree family history of BC | | | <0.001*† |
| Yes | 29 (11.6) | 1 (0.4) | |
| No | 221 (88.4) | 249 (99.6) | |
| A second-degree family history of BC | | | <0.001*† |
| Yes | 44 (17.6) | 6 (2.4) | |
| No | 206 (82.4) | 244 (97.6) | |
| C. Lifestyle factors | | | |
| Alcohol consumption | | | 1.000 |
| Yes | 2 (0.8) | 1 (0.4) | |
| No | 248 (99.2) | 249 (99.6) | |
| Smoking | | | 0.122† |
| Active smoker | 6 (2.4) | 1 (0.4) | |
| No smoker | 244 (97.6) | 249 (99.6) | |
| BMI | | | <0.001*† |
| Normal | 108 (43.2) | 160 (64.0) | |
| Overweight | 91 (36.4) | 62 (24.8) | |
| Obesity | 51 (20.4) | 28 (11.2) | |
| C. Lifestyle factors | | | |
| High-fat diet | | | <0.001*† |
| Excess | 240 (96.0) | 131 (52.4) | |
| Sufficient | 10 (4.0) | 119 (47.6) | |
| High-calorie diet | | | 0.466 |
| Excess | 97 (38.8) | 106 (42.4) | |
| Sufficient | 153 (61.2) | 144 (57.6) | |
| Physical activity | | | <0.001*† |
| Low | 79 (31.6) | 20 (8.0) | |
| Moderate | 112 (44.8) | 54 (21.6) | |
| Heavy | 59 (23.6) | 176 (70.4) | |

*, P < 0.05 was considered statistically significant; †, variables with P < 0.25 were included in the multivariable modeling; BC, breast cancer

Table 2. Crude and Adjusted Odds Ratios of Identified Risk Factors Associated with Breast Cancer among Indonesian Women

| Variables | Crude OR (95% CI) | Adjusted OR (95% CI) |
|---|---|---|
| Age (years) | | |
| <50 | 1 (Reference) | 1 (Reference) |
| ≥50 | 1.29 (0.91, 1.84) | 0.52 (0.23, 1.15) |
| Age at menopause (years) | | |
| <50 | 1 (Reference) | 1 (Reference) |
| ≥50 | 2.33 (1.63, 3.34)* | 4.50 (2.00, 10.12)* |
| Age at first pregnancy (years) | | |
| <20 | 1.25 (0.78, 2.01) | 0.95 (0.46, 1.97) |
| 20-29 | 1 (Reference) | 1 (Reference) |
| ≥30 | 2.91 (1.71, 4.95)* | 2.70 (1.11, 6.56)* |
| A first-degree family history of BC | | |
| Yes | 32.67 (4.42, 241.84)* | 30.22 (3.16, 293.09)* |
| No | 1 (Reference) | 1 (Reference) |
| A second-degree family history of BC | | |
| Yes | 8.69 (3.63, 20.79)* | 3.82 (1.05, 13.86)* |
| No | 1 (Reference) | 1 (Reference) |
| Breastfeeding duration (months) | | |
| <12 | 59.17 (8.10, 432.40)* | 41.24 (2.84, 598.42)* |
| ≥12 | 1 (Reference) | 1 (Reference) |
| Use of oral contraceptives (months) | | |
| <12 | 1 (Reference) | 1 (Reference) |
| ≥12 | 3.89 (2.51, 6.04)* | 1.94 (1.01, 3.74)* |
| Smoking | | |
| Active smoker | 6.12 (0.73, 51.23) | 11.86 (0.44, 321.10) |
| No smoker | 1 (Reference) | 1 (Reference) |
| BMI | | |
| Normal | 1 (Reference) | 1 (Reference) |
| Overweight | 2.17 (1.45, 3.26)* | 2.37 (1.28, 4.40)* |
| Obesity | 2.70 (1.60, 4.55)* | 3.94 (1.79, 8.66)* |
| High-fat diet | | |
| Excess | 21.80 (11.05, 43.01)* | 25.75 (10.71, 61.91)* |
| Sufficient | 1 (Reference) | 1 (Reference) |
| Physical activity | | |
| Low | 11.78 (6.65-20.89)* | 14.29 (6.64, 30.76)* |
| Moderate | 6.19 (3.40, 9.59)* | 4.08 (2.21, 7.53)* |
| Heavy | 1 (Reference) | 1 (Reference) |

*, P < 0.05 was considered statistically significant; BC, breast cancer; BMI, body mass index; OR, odds ratio

Table 3. Development of the Breast Cancer Risk Scoring System

| Variables | B | S.E | B/S.E | B/S.E/2.14 | Score |
|---|---|---|---|---|---|
| Age at menopause (≥ 50 years) | 1.01 | 0.28 | 3.61 | 1.69 | 2 |
| Age at first pregnancy (≥30 years) | 0.97 | 0.45 | 2.16 | 1.01 | 1 |
| A first-degree family history of BC | 3.34 | 1.15 | 2.90 | 1.36 | 1 |
| A second-degree family history of BC | 1.41 | 0.66 | 2.14 | 1.0 | 1 |
| Breastfeeding duration (<12 months) | 3.58 | 1.39 | 2.58 | 1.21 | 1 |
| Use of oral contraceptives (≥ 12 months) | 0.73 | 0.33 | 2.21 | 1.03 | 1 |
| Overweight | 0.96 | 0.31 | 3.10 | 1.44 | 1 |
| Obesity | 1.42 | 0.40 | 3.55 | 1.66 | 2 |
| High-fat diet | 3.23 | 0.45 | 7.18 | 3.36 | 3 |
| Low physical activity | 2.63 | 0.39 | 6.74 | 3.15 | 3 |
| Moderate physical activity | 1.45 | 0.31 | 4.68 | 2.19 | 2 |
| Total score | | | | | 18 |
| Breast cancer risk screening tool | -5.18 | 0.55 | | | |
| P-value = <0.001 | | | | | |

BC, breast cancer; S.E, standard error

For each subject score, the value of y was calculated, and the probability of poor prognosis (p) was determined using the logistic function p = 1/ 1 + exp (-y), with the result presented as both a decimal and a percentage. As the subject score increased, the probability of poor prognosis also increased. For example, at a subject score of 0, the calculated y value was -5.18, resulting in a poor prognosis probability of 0.6%. As the score rose, so did the probability, with a subject score of 18 resulting in a y value of 4.72, corresponding to a 99.1% probability of a poor prognosis. The table showed a progressive increase in risk with higher scores, highlighting the relationship between the total score and the likelihood of a poor outcome.

Diagnostic performance of the breast cancer risk score based on criterion values and ROC curve coordinates (Table 5). Table 5 presented the best balance between sensitivity, specificity, and likelihood ratios is observed at the threshold of >5, where sensitivity remains reasonably high (84%) and specificity improves to 80%, with a +LR of 4.20. Based on these findings, the cut-off point for distinguishing between high-risk and low-risk groups for BC is determined to be a cut-off score of >5. This threshold provides an optimal trade-off between identifying true positives and minimizing false positives, making it a suitable choice for classifying individuals based on their risk level.

ROC curve for assessing the accuracy of the BC risk screening tool (Figure 1). Figure 1 presented the ROC curve for assessing the accuracy of the BC risk screening tool. The Area Under the Curve (AUC) was 0.907, with a 95% CI of 0.879-0.931, and the p-value was <0.001, indicating that the screening tool was highly accurate and statistically significant.

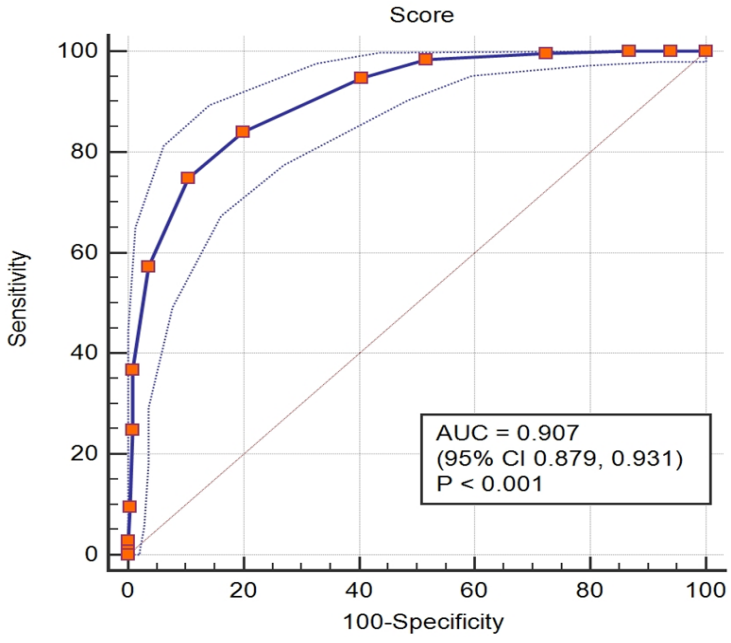


Figure 1. ROC Curve for Assessing the Accuracy of the Breast Cancer Risk Screening Tool

Table 4. Calculation of Poor Prognosis Probability based on Breast Cancer Risk Score

| Subject score | a constant | Coefficient | y = -5.18 + 0.55 x total score | p = 1/ 1 + exp (-y) | p (%) |
|---|---|---|---|---|---|
| 0 | -5.18 | 0.55 | -5.18 | 0.006 | 0.6% |
| 1 | -5.18 | 0.55 | -4.63 | 0.010 | 1.0% |
| 2 | -5.18 | 0.55 | -4.08 | 0.017 | 1.7% |
| 3 | -5.18 | 0.55 | -3.53 | 0.028 | 2.8% |
| 4 | -5.18 | 0.55 | -2.98 | 0.050 | 4.8% |
| 5 | -5.18 | 0.55 | -2.43 | 0.081 | 8.1% |
| 6 | -5.18 | 0.55 | -1.88 | 0.132 | 13.2% |
| 7 | -5.18 | 0.55 | -1.33 | 0.209 | 20.9% |
| 8 | -5.18 | 0.55 | -0.78 | 0.314 | 31.4% |
| 9 | -5.18 | 0.55 | -0.23 | 0.442 | 44.2% |
| 10 | -5.18 | 0.55 | 0.32 | 0.579 | 57.9% |
| 11 | -5.18 | 0.55 | 0.87 | 0.705 | 70.5% |
| 12 | -5.18 | 0.55 | 1.42 | 0.805 | 80.5% |
| 13 | -5.18 | 0.55 | 1.97 | 0.878 | 87.8% |
| 14 | -5.18 | 0.55 | 2.52 | 0.925 | 92.5% |
| 15 | -5.18 | 0.55 | 3.07 | 0.956 | 95.6% |
| 16 | -5.18 | 0.55 | 3.62 | 0.973 | 97.3% |
| 17 | -5.18 | 0.55 | 4.17 | 0.984 | 98.4% |
| 18 | -5.18 | 0.55 | 4.72 | 0.991 | 99.1% |

exp, exponential; p, probability

## Discussion

This study developed a scoring system for predicting BC risk among Indonesian women, particularly in regions with limited healthcare infrastructure. Several reproductive, familial, and lifestyle determinants were found to be significantly associated with BC, including late menopause, delayed first pregnancy, family history, shorter breastfeeding duration, long-term use of oral contraceptives, high BMI, high-fat diet, and low levels of physical activity.

The association between later menopause and increased BC risk observed in this study (adjusted OR 4.50) is consistent with evidence from Western cohorts, where prolonged lifetime estrogen exposure has been strongly linked to tumor development [29, 30]. Similar results were reported in large-scale studies in the United States and Europe, reinforcing the biological plausibility of this risk factor [29-31]. A previous meta-analysis also demonstrated that the cumulative duration of estrogen exposure from menarche to menopause is linearly associated with breast cancer risk, highlighting the importance of reproductive hormonal balance in carcinogenesis [19].

Delayed first pregnancy (≥30 years) also emerged as a significant risk factor (adjusted OR 2.70), consistent with

Table 5. Diagnostic Performance of the Breast Cancer Risk Score based on Criterion Values and ROC Curve Coordinates

| Criterion | Sensitivity | 95% CI | Specificity | 95% CI | +LR | -LR |
|---|---|---|---|---|---|---|
| ≥0 | 100.00 | 98.5 – 100.0 | 0.00 | 0.0 – 1.5 | 1.00 | |
| >1 | 100.00 | 98.5 – 100.0 | 13.20 | 9.3 – 18.0 | 1.15 | 0.00 |
| >2 | 99.60 | 97.8 – 100.0 | 27.60 | 22.2 – 33.6 | 1.38 | 0.014 |
| >3 | 98.40 | 96.0 – 99.6 | 48.40 | 42.1 – 54.8 | 1.91 | 0.033 |
| >4 | 94.80 | 91.3 – 97.2 | 59.60 | 53.2 – 65.7 | 2.35 | 0.087 |
| >5 | 84.00 | 78.9 – 88.3 | 80.00 | 74.5 – 84.8 | 4.20 | 0.20 |
| >6 | 74.80 | 68.9 – 80.1 | 89.60 | 85.1 – 93.1 | 7.19 | 0.28 |
| >7 | 57.20 | 50.8 – 63.4 | 96.40 | 93.3 – 98.3 | 15.89 | 0.44 |
| >8 | 36.80 | 30.8 – 43.1 | 99.20 | 97.1 – 99.9 | 46.00 | 0.64 |
| >9 | 24.80 | 19.6 – 30.6 | 99.20 | 97.1 – 99.9 | 31.00 | 0.76 |
| >10 | 9.60 | 6.2 – 13.9 | 99.60 | 97.8 – 100.0 | 24.00 | 0.91 |
| >11 | 2.80 | 1.1 – 5.7 | 100.00 | 98.5 – 100.0 | | 0.97 |
| >13 | 0.00 | 0.0 – 1.5 | 100.00 | 98.5 – 100.0 | | 1.00 |

CI, confidence interval; +LR, positive likelihood ratio; -LR, negative likelihood ratio

findings from China and Korea, where urbanization and shifting reproductive patterns have contributed to rising BC incidence [32, 33]. However, in contrast to Western settings where nulliparity is a more dominant factor, multiparity remains relatively common in Indonesia, and the protective role of early childbirth is more evident [4]. This is in line with global epidemiological models showing that earlier full-term pregnancy promotes terminal differentiation of breast epithelial cells, thereby reducing susceptibility to malignant transformation [11, 18].

Family history of BC, particularly in first-degree relatives, demonstrated an exceptionally strong association (adjusted OR 30.22). This result underscores the genetic contribution to BC risk and mirrors findings from high-income countries, where BRCA1/2 mutations and other hereditary syndromes account for a substantial proportion of familial cases [34, 35]. However, in Indonesia, limited access to genetic counseling and testing hampers the identification of at-risk families. A previous comparative meta-analysis involving Malaysian and Indonesian women also showed consistently elevated odds ratios for family history, reflecting shared genetic ancestry and environmental exposures within families [12].

Breastfeeding for less than 12 months was associated with a strikingly higher risk (adjusted OR 41.24), which is more pronounced than in studies from Malaysia and Nigeria [36, 37]. This difference may reflect variations in breastfeeding practices, where cultural and economic pressures in some Indonesian communities shorten breastfeeding duration [4, 21, 22]. Encouraging prolonged breastfeeding could therefore be a particularly impactful intervention in this context.

Lifestyle factors also contributed significantly to BC risk. Obesity and overweight were associated with nearly fourfold and twofold increased risks, respectively, consistent with global evidence linking excess body fat to increased estrogen production and chronic inflammation [6, 8, 9]. Similarly, high-fat diet and low physical activity were among the strongest predictors in this study, echoing results from African and South Asian populations [8, 9], where nutrition transition and sedentary behaviors are reshaping cancer risk profiles [13, 14]. An Indonesian dataset also shows that high-fat dietary patterns and rising BMI trends are becoming major public health challenges, especially in rapidly urbanizing regions undergoing significant lifestyle changes [14].

The scoring system developed in this study provides a feasible tool for risk stratification in low-resource settings [16]. It can be applied at the primary healthcare level to identify high-risk women and prioritize them for further screening, such as clinical breast examination or mammography where available. Integrating this tool into existing maternal and child health services could enhance coverage, as women frequently access these programs during reproductive years [16, 38]. A screening model study from England indicates that risk-stratified screening improves efficiency, reduces unnecessary imaging, and enhances the targeted allocation of resources [38]. Adapting this approach could offer substantial benefits for the Indonesian healthcare system.

Public health interventions should focus on modifiable risk factors. Community-based programs promoting prolonged breastfeeding, healthy diet, and regular physical activity could substantially reduce risk [4]. For example, in Thailand, grassroots women's health initiatives that combined peer education with practical support for breastfeeding and physical activity have led to measurable improvements in women's health behaviors [39]. Similar culturally tailored programs could be implemented in Indonesia.

Strengthening awareness campaigns is also critical. In a country like Uganda, mobile health platforms have been successfully used to disseminate cancer prevention messages and improve health literacy in rural communities [40]. Leveraging mobile phone penetration in Indonesia could expand outreach to underserved areas.

A key strength of this study is its hospital-based case–control design with a relatively large sample size, which enabled the identification of both reproductive and lifestyle-related risk factors. The development of a scoring system based on locally relevant predictors addresses a critical gap, as existing international models are poorly adapted to the Indonesian context. The high accuracy of the tool, with an AUC of 0.907, demonstrates its potential utility in practice.

However, several limitations should be acknowledged. First, as a hospital-based study, the findings may not fully represent the broader community, particularly women who do not access tertiary healthcare services. Second, self-reported lifestyle factors such as diet and physical activity are subject to recall and reporting bias. Third, genetic testing was not available, limiting the ability to differentiate hereditary syndromes from familial clustering. Finally, while the scoring system showed good discriminatory power, external validation in community-based cohorts and in other provinces is necessary before widespread implementation.

These findings provide important implications for practice, prevention, policy, and future research. Policymakers should strengthen primary-level breast cancer prevention by incorporating risk-stratified screening into existing reproductive health services and supporting culturally tailored programs that target modifiable lifestyle risks. The scoring tool developed in this study can be directly integrated into primary care settings to help healthcare workers in low-resource areas identify high-risk women and facilitate early referral. Increasing public awareness of familial and hereditary factors remains essential. For prevention efforts, the results reinforce the need to promote healthy BMI, physical activity, and prolonged breastfeeding through community-focused education. At the policy level, integrating this risk tool into digital health platforms and strengthening referral pathways would enhance early detection capacity. Future research should validate the scoring system in diverse populations, explore mobile-based applications to improve accessibility, and incorporate genetic or biomarker data as these become available.

Concrete interventions that could help bridge existing gaps include establishing "Breast Health Corners" within Puskesmas to provide systematic clinical breast examinations and risk scoring, deploying mobile

mammography units to reach remote districts in West Sumatra, incorporating structured breast cancer modules into community-based health service post (Posyandu), and school-based health programs. Training community health workers (kader) to conduct house-to-house education and creating mosque or school-based awareness campaigns tailored to local cultural norms would further strengthen early detection. Regional governments could also pilot incentive-based targets for early detection performance across Puskesmas networks.

## Author Contribution Statement

RDN conceptualized the study, developed the methodology, conducted the investigation, performed the analysis, and drafted the manuscript. MN validated the findings and contributed to manuscript revision. SS contributed to methodology and manuscript revision. NAA and FARP performed the investigation and contributed to manuscript revision.

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*Ethical Declaration*

Ethical approval was obtained from the Ethics Committee of Dr. M. Djamil Hospital, Padang, Indonesia (No. DP.04.03/D.XVI.XI/401/2025). Written informed consent was obtained from all participants prior to enrollment and data collection.

*Data Availability*

The data underlying the results presented in thie study are available from the corresponding author upon reasonable request.

*Conflict of Interest*

Nil.

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